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Interim Guidelines for the Remediation of Petroleum Contamination at Operating Retail and Private Fuel Outlets in Ontario

Report of the Petroleum Contaminated Soils Working Group
January 20, 1992
(Revised March 5, 1992)

Hazardous Contaminants Branch
Ontario Ministry of the Environment

APPENDIX C:
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APPENDICES

1.0 Purpose

The purpose of these guidelines is to provide interim clean-up criteria for sites contaminated by petroleum products (primarily gasoline, diesel, and fuel and waste oils) released from underground storage tanks (USTs) or lines/pumps at commercial sites. The guidelines specifically refer to on-site contamination at operating retail and private fuel outlets (excluding refineries and petrochemical plants) where no change in land use is intended.

2.0 Background and Approach

On-site inspection and remediation of spills, leaks, and releases of petroleum products is the responsibility of the Fuels Safety Branch of the Ministry of Consumer and Commercial Relations (MCCR). Under a working agreement, the Ministry of the Environment (MOE), provides MCCR with advice and recommendations with respect to on-site as well as off-site remediation where its primary responsibility lies. Currently in Ontario clean-up criteria are applied on a somewhat *ad hoc* basis and there is an urgent need for consistent guidelines throughout the various regions of the province. Accordingly, in October of 1991, a meeting was organized by R. Hore (Director, NE Region, MOE) and I. Wile (Director, Hazardous Contaminants Branch, MOE) which included representatives of the Canadian Petroleum Products Institute (CPPI) and other Ministry staff. It was agreed that a Working Group composed of representatives from CPPI and Ministry branches and regions be established to examine what options were available with respect to development of new or adoption of existing guidelines. It was envisaged that the interim guidelines would be valid until other Ministry initiatives, in particular the Materials Policy Committee, would develop and provide more long-term soils criteria.

Given the urgent need for guidelines and their proposed interim nature, it was not felt to be practical to develop new criteria but rather the approach would involve examining existing criteria of other jurisdictions to see if they could in some way be adopted for use in Ontario. The approach used by the Working Group to select interim guidelines involved a number of specific tasks:

- A review of the constituents of petroleum products in Ontario.
- A review and selection of the most appropriate indicator compounds.
- An examination of current practices in Ontario.
- An examination of the protocols and criteria used in other jurisdictions to manage petroleum contaminated soils and their rationale.
- Selection and recommendation of the most practical option for Ontario by January, 1992.

3.0 Constituents of Petroleum Products in Ontario

Gasoline and diesel fuels are complex mixtures of hydrocarbons with diesel containing more of the heavier hydrocarbons. Both fuels may contain up to 50% aromatics with the remainder primarily composed of paraffins, napthenes, and olefins. The most important of these aromatics from a toxicological point of view are believed to be the BTEX compounds: benzene, toluene, ethylbenzene, and xylenes which together may constitute up to 30% by weight. Of additional concern are phenols, PAHs such as napthalene, and numerous additives such as MMT (methylcyclopentadienylmanganese tricarbonyl) and MTBE (methyl-tert-butyl ether). The latter additive has received considerable regulatory interest in the United States and has just recently been introduced into some Ontario fuels. Information on the nature and proportions of most additives is not available for proprietary reasons. An analysis of several Ontario gasolines by the Alberta Research Council in 1989 (conducted for CPPI) revealed the following proportions of BTEX components:

Table 1: BTEX Composition of Gasoline

	Gasoline	
Component	Regular Unleaded	Premium Unleaded
benzene	2.9%	2.8%
toluene	9.6%	10.5%
ethylbenzene	1.7%	2.0%
xylenes	10.0%	11.6%

Similar information is not available for diesel fuels in Ontario however it is known that diesel fuels are made up of heavier hydrocarbons and typically contain a lower concentration of the lighter aromatics. Benzene may for example only be present at 0.1% by weight.

4.0 Indicator Compounds

There is a certain amount of controversy over which indicator compounds are the most appropriate in terms of providing the most protective soil and groundwater criteria which are scientifically-based. The BTEX components have typically been considered the primary substances of concern because of their known toxic, aesthetic or (in the case of benzene) carcinogenic effects. They are also highly mobile and may be expected to migrate furthest from the source of contamination. In groundwater contamination for example, they may account for up to 90% of the contamination problem. Some jurisdictions have developed criteria which use a total BTEX number rather than the individual components however this value assumes all components are equally as toxic and therefore may not be protective if the major contaminant is benzene. It should be noted that BTEX components only make

up to one third of the constituents in gasolines and much less in diesel fuels. The remaining compounds are not necessarily innocuous and should not be discounted simply because of a lack of toxicological data.

Total petroleum hydrocarbon (TPH) analyses have been used which measure the total of aliphatic as well as aromatic hydrocarbons such as the BTEX components. This information can be used to help determine the extent of hydrocarbon contamination in the soil and possibly to fingerprint the petroleum product. Depending on the volatility of the product spilled, soil characteristics, and the age of the release or spill, analysis for the more volatile BTEX components may not in itself be sufficient. As well the absence of high BTEX levels may not ensure the absence of petroleum product odors or other adverse effects. For these reasons the analysis of both BTEX components and TPH levels is warranted. Some jurisdictions have used only a TPH criterion but have set a very low level to ensure capture of the BTEX components. Analytical difficulties and the difficulty in establishing a meaningful health-based criterion means that TPH has been considered more of a management value.

Oil and grease (1% for fresh oil; 2% for weathered oil) criteria have been used in Ontario however they are derived from the 1989 Ontario Waste Management Decommissioning Guidelines and are very loosely based on phytotoxicity considerations. Oil and grease criteria have also been used in other Canadian provinces (i.e. Quebec, British Columbia) in the range of 0.01% to 0.5% however the basis upon which these numbers were established is not clear. Aesthetic effects (odours, staining,etc) may be present at levels higher than 0.5%.

Other indicator compounds with known toxicity characteristics are lead, which has historically been a major component of gasolines in Ontario, and phenols whose major impact are most likely adverse aesthetic effects on potable water supplies. Lead is rarely a contamination problem of soils at continuing use service stations in Ontario. Phenols are sometimes found at concentrations above drinking water guidelines in natural environments. PAH contamination may be a characteristic of certain aged sites or sites where waste oils are a problem.

The substances considered to be the most important in terms of establishing clean-up criteria for soils and groundwater for continuing use sites in Ontario are:

- benzene
- toluene
- ethylbenzene
- xylenes
- TPH

Other contaminants such as PAHs and trace metals may be present and may require site specific risk assessments on a case by case basis. However in most clean ups involving

continuing use sites criteria for the above listed substances should provide adequate protection.

5.0 Review of Other Jurisdictions' Criteria and Rationale

The criteria and the rationale for using those criteria (where available) established by many jurisdictions including The Netherlands, all Canadian provinces and most U.S. states were examined.

5.1 Canada

In Canada there has historically been a heavy reliance on the use of the Netherlands "A,B,C" system which identified three investigation/action thresholds for contaminated sites. These were initially based on background levels (Level A) with multiples of the A levels used for the B and C levels. A similar system was adopted by Quebec with minor changes (these guidelines are currently undergoing revision) and by Saskatchewan. In British Columbia the same system has been used except that the investigation thresholds referred more specifically to background (Level A), residential (Level B), and industrial/commercial sites (Level C). Criteria adopted by the Canadian Council of Ministers of the Environment (CCME) as interim decommissioning criteria were primarily based on existing provincial criteria using land use to establish site sensitivity. Most jurisdictions take into account site sensitivity and risk by considering different clean-up levels according to site setting or land use. There is little scientific justification for use of most of these numerical criteria except perhaps for their widespread usage and the fact that the B and C levels are multiples of background levels and hence incorporate reasonable safety factors. The range of soil criteria used in Canadian jurisdictions is presented in Table 2.

More recently in Canada, the Alberta Management of USTs (MUST) program has adopted human health risk-based criteria specifically developed for petroleum contaminated sites which were independently developed and reviewed by professional consultants. These criteria have also been fully or partially adopted for use in Saskatchewan, Nova Scotia, and P.E.I. (for TPH), and have seen some application in Ontario. It should be noted that although the criteria used in most Canadian jurisdictions appear to be very similar, there are large differences in the way the criteria are applied. The lowest levels in one jurisdiction may refer to agricultural land or background levels whereas in another jurisdiction they may refer to a high sensitivity site irrespective of land use. The Alberta criteria for example correspond to three levels of site sensitivity: Level I (high), Level II (moderate), and Level III (low) based on land use, groundwater use, receptor sensitivity, and likelihood of impact (see Appendix A for abstracts of criteria and rationales used for selected jurisdictions).

Table 2: Soil Criteria Used in Canada for Selected Petroleum Constituents	
Contaminant	Range (ppm)
Benzene	0.05 to 5.0
Toluene	0.1 to 100
Ethylbenzene	0.1 to 100
Xylenes	0.1 to 50
TPH	5 to 10,000

5.2 United States

In the United States the EPA governs many aspects of UST removal and replacement but allows soil and groundwater remediation criteria to be established by local or state agencies. Many states have developed comprehensive guidelines covering reporting requirements, site investigation, sampling design, and remediation methods. The criteria range from single TPH values to comprehensive sets of numbers covering all possible contaminants found as a result of petroleum spills or leaks. Most BTEX criteria are based to a large degree on drinking water standards - particularly in those states (e.g. California) where groundwater protection is crucial. Many states (e.g. Kansas, Washington, California) use a complex matrix/ranking system to establish the potential for impact on groundwater and hence the levels of TPH and BTEX which can be left on-site. A similar approach is used in North Carolina unless a human exposure pathway is identified in which case a site-specific risk assessment is required (see Appendix A). The range of soil criteria used for BTEX and TPH in the United States is presented in Table 3.

Table 3: Soil Criteria Used in the United States for Selected Petroleum Constituents[1]	
Contaminant	Range (ppm)
Benzene	0.015 to 3.8
Toluene	0.3 to 724
Ethylbenzene	0.6 to 125
Xylenes	0.4 to 240
TPH	10 to 10,000

[1]For BTEX the ranges include data from published UST program criteria as well as site-specific health-based criteria from the EPA Superfund's Records of Decision Database.

6.0 Selection of Soils Criteria for Ontario and Rationale

Based on a review of all available criteria and protocols of Canadian and U.S. jurisdictions a modified set of the Alberta MUST values has been selected for use in Ontario. The Alberta MUST criteria represent the only comprehensive set of criteria available which are human health risk-based and which were developed specifically for petroleum contaminated sites. They were developed using a standard EPA-recommended methodology and consider land use, groundwater use, receptor sensitivity, and the likelihood of adverse impacts.

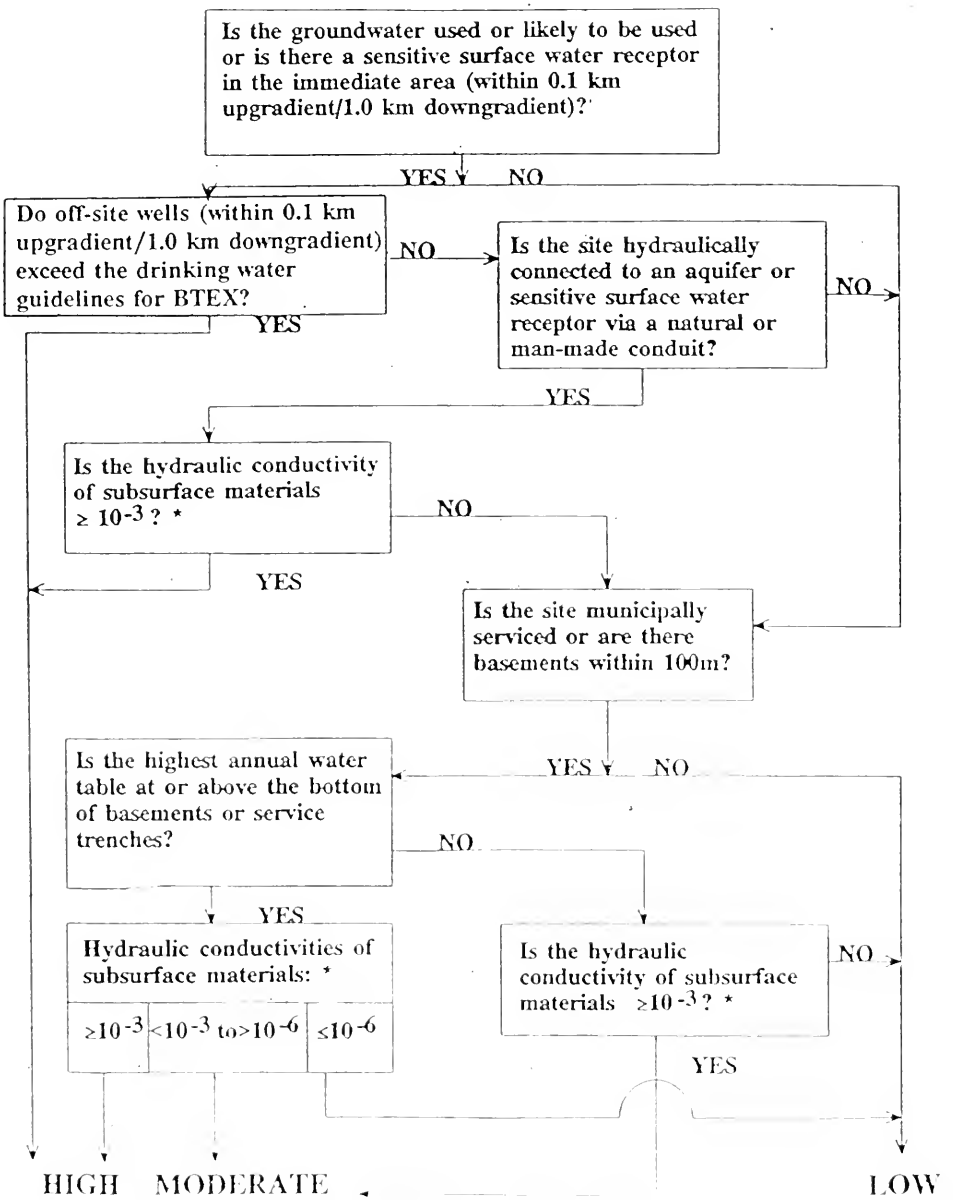
6.1 Site Sensitivity

The Alberta MUST guidelines contain a comprehensive approach to determining site sensitivity and hence determining the appropriate clean-up level: Level I (high sensitivity) defined as a site whose general characteristics suggest that even a small amount of contaminants, if left in place, might pose significant human health or safety problems in the future; Level II (moderate sensitivity); and Level III (low sensitivity) defined as a site whose location, surrounding land use and other conditions are such that the likelihood of contaminants affecting potentially sensitive receptors is minimal. The approach considers virtually all environmental factors and exposure pathways which might influence site sensitivity but unfortunately does not explicitly state the key parameter values (i.e. distance to receptor) which determine site sensitivity, perhaps because of the large number of site-specific factors which can influence a site-sensitivity decision. The approach may therefore be too subjective. In Ontario, petroleum contamination at operating commercial sites impacts, or has the potential to impact, off-site human and environmental receptors most often as a result of the following set of factors:

- actual or potential groundwater contamination
- proximity of the site to sensitive receptors
- presence of underground conduits (i.e. servicing trenches)
- soil types and hydraulic conductivity

A decision-tree approach was therefore thought to be the simplest, most objective, and most appropriate mechanism for determining site sensitivity at commercial sites (see Figure 1). The approach considers the dominant forms of exposure to be ingestion of contaminants from drinking water and inhalation of vapours from water and soils, and assumes that the risks associated with direct contact with soil are minimal. Using the above noted factors, the decision tree directs the proponent to a specific level of site sensitivity corresponding to a specific soil clean-up level (Table 4). The decision tree requires knowledge of hydraulic conductivities of subsurface materials. Appendix B contains typical values which, providing the site investigation is carried out by experienced professionals, may be used in place of field hydraulic conductivity tests.

Figure 1: Generic Site Sensitivity Analysis



* when greater than 2/3 of the subsurface materials (from surface to water table) are of a particular type the site will normally be considered to be composed of that type of material. All values are cm/s. See also Appendix B.

6.2 Soil Remediation Criteria

The primary objectives of the soil criteria are to a) establish on-site clean-up levels which are not expected to cause adverse off-site effects and b) to protect on-site users. It should be noted that even soils remediated these levels are not "clean" soils and may not allow for unrestricted future land use. Typical "background" levels of these contaminants in Ontario soils are being obtained as part of the Materials Policy initiative but are not yet available.

Table 4: Interim Soil Remediation Criteria for Petroleum Contamination at Operating Commercial Sites (ug/g or ppm)

	Site Sensitivity		
Contaminant	Level I (HIGH)	Level II (MODERATE)	Level III (LOW)
Benzene	0.05	0.5	2.0
Toluene	1.0	10.0	100
Ethylbenzene	0.5	5.0	100
Xylenes	1.0	5.0	50
TPH	100	1000	5000

6.3 Rationale for Soils Criteria

The three values for benzene are based on a simplified health risk assessment conducted using standard EPA-recommended methodology with a target inhalation cancer risk of 10^{-6}. For toluene, ethylbenzene, and xylenes, the Level I values are health objectives based on inhalation of soil vapours and ingestion of groundwater using acceptable daily intakes or reference doses for a typical site with high sensitivity. The level II and III values are based on Alberta Hazardous Waste regulations and the "B" and "C" level criteria of other jurisdictions. All the Level II and III values are in the range of those values currently being used in most North American jurisdictions.

In terms of TPH, health-based criteria are not available. The original Alberta criteria for TPH were based on the assumption that diesel contains 0.1% benzene; an assumption which may not be valid. Because of the difficulty in establishing meaningful health-based TPH criteria, TPH values represent management numbers used primarily to a) protect against adverse aesthetic effects such as odors and staining (see also section 4.2) and b) protect against the non-BTEX components present at aged sites or sites contaminated by heavier

fuels. The TPH values also reflect our minimal knowledge concerning the composition of fuel products and the toxicology of the non-BTEX components. The TPH criterion for highly sensitive sites (100 ppm) is a common action level or soil objective used in several Canadian jurisdictions and at least 16 U.S. States. In California, where regulators have considerable experience analyzing and modelling the leaching potential of hydrocarbons from soil to groundwater, the value is considered to be protective of groundwater. This is consistent with our own site sensitivity analysis where high sensitivity sites most often involve a high potential impact on groundwater. The value of 1000 ppm for moderately sensitive sites represents the upper limit for diesel contamination at sites with a moderate potential for impact on groundwater (i.e. in California, Idaho, Oregon). It also corresponds to the Quebec "B" level. The low sensitivity value of 5000ppm should avoid the adverse aesthetic effects/resource protection problems present at higher levels of contamination and also corresponds to the Quebec/B.C. "C" levels for oil and grease. With the exception of California, where a TPH (diesel) value of 10,000 ppm may be allowed in special cases, no jurisdictions permit higher levels of contamination.

7.0 Groundwater

In Ontario, MOE policy and legislation protects the current and future use of groundwater under the Water Resources Act (sections 14-17) the Environmental Protection Act (sections 5,6,12-16) and the Reasonable Use policy. Groundwater contamination problems are handled on a case-by-case basis so that whenever possible groundwater quality is maintained. Proponents must consult closely with Regional M.O.E. staff whenever there is a suspected or actual groundwater problem to determine an appropriate course of action. For reference purposes the Ontario Drinking Water Objectives are shown for selected petroleum constituents in Table 5.

Table 5: Ontario Drinking Water Objectives for Selected Petroleum Constituents[1]

Contaminant	Drinking Water Objective[2]
Benzene	0.005
Toluene	0.024
Ethylbenzene	0.002
Xylenes	0.300
Phenols	0.002
Lead	0.010

[1] all values are ppm

[2] Ontario Drinking Water Objectives/Canadian Drinking Water Guidelines

8.0 Minimum Generic Guidelines

In addition to specific remediation criteria there are a number of minimum conditions which must be met as part of the remediation process. These include:

- removal of all free liquid product.
- elimination of any explosion hazards (gasoline LEL: 13,000ppm)
- elimination of hydrocarbon vapours in on-site enclosed spaces to below Ministry of Labour guidelines.
- elimination of any adverse impacts caused by odours or visible hydrocarbon staining (per EPA section 13).

9.0 Site Specific Risk Assessments

In certain cases the proponent may not consider the clean up level indicated by the site sensitivity decision tree to be appropriate and/or feasible. In such cases the proponent may wish to perform a site specific risk assessment to develop clean up objectives more appropriate to the specific set of site conditions, land use and exposure scenarios involved. Such risk assessments would normally be conducted by professionals experienced in risk assessment methodology and may require detailed information over and above the investigation requirements set out below. A site specific risk assessment may also be required if contaminants were found at the site for which no numerical criteria are available. Specific protocols for conducting risk assessments are currently undergoing development by the CCME.

In certain cases where contaminated sites are found to be in close proximity to an acutely sensitive environmental receptor (i.e. wildlife habitat) the proponent may be required to conduct a site specific risk assessment and/or remediate to levels other than those indicated by the decision tree.

10.0 Site Investigation Requirements

In order to accurately determine the nature and extent of contamination, and to properly assess the potential impact of the contamination on human and environmental health, a detailed site investigation should be conducted. It is recognized however, that in the case of very minor spills and releases, the information required to assess the problem will be much smaller in scope.

10.1 Information Requirements

The following information should, in most cases, allow for a proper assessment of the extent of the contamination problem and the likelihood of adverse impacts on receptors.

a) Site History and Setting:

- past (if known) and present contents of tanks
- tank/tank line history including maintenance and upgrading
- location of underground tanks, pumps and lines
- history of previous discharges/leaks if available
- current land use within 100m of the site (type, distance, and direction)
- presence of nearby underground structures including the presence of basements or similar structures within 100m, distance to nearest underground structure in each direction, and the presence of buried utilities on or adjacent to the site
- proximity of any acutely sensitive environmental receptors

b) Groundwater:

- distance and direction to nearest wells within 1 km downgradient and 0.1 km upgradient and their use (private, municipal, etc.)
- depth to usable aquifer/depth to water table
- direction of regional groundwater flow
- presence and direction of vertical gradients
- presence and extent of phase-separated product at the water table, as appropriate
- concentrations of dissolved contaminants in groundwater as appropriate

d) Surface Water:

- distance to surface water bodies within 1 km
- type and drainage direction
- downstream uses

e) Soils:

- stratigraphy and approximate hydraulic conductivities

- depth and lateral extent of contamination
- concentrations of contaminants in soil
- presence of phase-separated product in soil

10.2 Use of Combustible Vapour Measurements

Combustible soil vapour measurements are widely used in Ontario and other jurisdictions as a field screening technique to determine the extent of the contamination problem. These measurements can vary widely however depending on many factors including the type of equipment used, the sampling techniques used, and the physical properties of the site soils. They may also not accurately reflect the extent of contamination at aged sites.

In all cases confirmatory laboratory analyses for BTEX as well as TPH must be conducted before the remediation process is considered to be complete. In the case of diesel or heavier fuel contamination, where BTEX concentrations are very low, reliance on vapour levels to determine the extent of contamination may not be appropriate.

11.0 Additional Guidelines

Further guidelines concerning analytical protocols for contaminants, sampling designs, groundwater investigation requirements, monitoring and verification requirements, and treatment and disposal options may be developed in the near future.

12.0 Feedback

If you have any concerns or comments with the above guidelines please do not hesitate to write:

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Appendix A: Soil and Groundwater Criteria Used in Selected Jurisdictions

Jurisdiction/Agency:

Alberta (February, 1991)

Approach:

Site sensitivity and risk-based clean-up levels.

Description and Rationale:

Under the proposed Alberta MUST program, Proponents must first conduct a detailed site investigation after which the Proponent may elect to clean up the site to stringent *de minimus* criteria. Alternatively, a site sensitivity analysis may be performed by a qualified professional on behalf of the Proponent which would result in a qualitative sensitivity ranking (based on receptor sensitivity and likelihood of impact) of each site as high (most sensitive), moderate, or low (least sensitive). This would involve an assessment of land use and site-specific factors which might affect the relationship between existing contamination and human and environmental risk. Sites with high sensitivity would normally require clean up to *de minimus* (Level I) criteria. Moderately sensitive sites would require remediation to somewhat less stringent (Level II) criteria and sites with low sensitivity would require remediation to the least stringent (Level III) criteria. In cases where the Proponent did not consider the clean up levels to be appropriate or feasible, a site specific risk assessment could be performed which might or might not suggest clean up criteria different than Levels I, II, or III.

Criteria:

Proposed Clean Up Criteria (ppm)						
	Level I		Level II		Level III	
Contaminant	soils	water	soils	water	soils	water
benzene	0.05	0.005	0.5	0.050	2.0	0.250
toluene	1.0	0.024	10.0	40	100	100
ethylbenzene	0.5	0.002	5.0	10	100	50
xylenes	1.0	0.300	5.0	5	50	20
TPH	40	0.200	400	50	2000	200
phenols	0.05	0.002	1.0		10	
lead	50	0.050	200		600	

Jurisdiction/Agency:

The Netherlands

Approach:

Generic clean-up levels for all contaminated sites

Description and Rationale:

Level A criteria represent background levels. Concentrations in excess of Level B require investigation and possible clean up over time while concentrations in excess of Level C require more immediate clean up. Level A values are primarily based on detection limits, Level B values are based on toxicity and aesthetic considerations, while Level C values are for the most part fixed multiples of Level B values. The system has been used successfully for a number of years.

Criteria:

Netherlands Criteria for Soils (ppm)			
	Level A	Level B	Level C
Contaminant			
benzene	0.01	0.5	5
toluene	0.05	3	30
ethylbenzene	0.05	5	50
xylenes	0.05	5	50
gasoline	20	100	800
phenols	0.02	1	10
lead	50	150	600
total aromatics	0.1	7	70

Jurisdiction/Agency:

Quebec (undergoing revision)

Approach:

Generic approach based on the Netherlands A, B, C system.

Description and Rationale:

A: Background level or detection limit level.

A-B: Soil or groundwater slightly contaminated. Decontamination usually not undertaken unless land redeveloped for especially sensitive uses.

B: Contamination threshold at which thorough analyses are required.

B-C: Soil or groundwater is contaminated. Soil will not automatically be contaminated. However restrictions may be imposed on land use and restoration may be required depending on land use.

C: Serious contamination threshold at which prompt remedial action may be necessary. Above this level all land uses will likely be restricted and restoration undertaken prior to rehabilitation.

Criteria:

Quebec Soil Criteria Values (ppm)

	Level A	Level B	Level C
Contaminant			
benzene	0.1	0.5	5
toluene	0.1	3	30
ethylbenzene	0.1	5	50
xylenes	0.1	5	50
gasoline	100	150	800
oil and grease*	100	1000	5000
phenols	0.1	1	10
lead	50	200	600

* values are ppm for soils, ppb for groundwater

Jurisdiction/Agency:

Manitoba (April, 1991)

Approach:

Generic approach based on the Quebec system. Department of Environment may adjust values up or down on a site-specific basis.

Description and Rationale:

Soils with less than 100 ppm TPH do not require remediation; soils with 100 to 800 ppm TPH may require remediation depending on future land usage and environmental risk; soils with greater than 800 ppm TPH must be treated.

Criteria:

see Quebec

Jurisdiction/Agency:

British Columbia

Approach:

Generic clean up levels based on the Netherlands/Quebec system with more explicit land use considerations.

Description and Rationale:

A: Background levels and investigation threshold for residential land. For contaminant concentrations between A and B, the soil is considered slightly contaminated but remediation is not required.

B: Remediation standard for residential land and investigation threshold for industrial land. Remediation to concentrations less than level B is required if the land is to be used as residential or recreational.

C: Remediation standard for industrial land. At concentrations exceeding the the C level all land uses will be restricted pending remediation.

Criteria:

British Columbia Soil Criteria Values (ppm)

Contaminant	Level A	Level B	Level C
benzene	0.1	0.5	5
toluene	0.1	3	30
ethylbenzene	0.1	5	50
xylenes	0.1	5	50
gasoline	100	150	800
oil and grease*	100	1000	5000
phenols	0.1	1	10
lead	50	500	1000
light aliphatic hydrocarbons**	100	150	800

*100 ppb for groundwater/surface water; **1000 ppb for groundwater/surface water

Jurisdiction/Agency:

Canadian Council of Ministers of the Environment (CCME)

Approach:

Interim environmental quality criteria for contaminated sites.

Description and Rationale:

Interim contaminant-specific guidelines governing the remediation of soils and water at contaminated sites to the lowest practical levels. They were adopted from existing guidelines and criteria currently being used in Canada. They apply to all contaminated sites with the provision that local conditions and land uses are considered in their application.

Criteria:

	Soil			Water
Contaminant	Agricultural	Residential/Parkland	Commercial/ Industrial	Drinking Water
benzene	0.05 ppm	0.5 ppm	5 ppm	5 ppb
ethylbenzene	0.1 ppm	5 ppm	50 ppm	<2.4 ppb
toluene	0.1 ppm	3 ppm	30 ppm	<24 ppb
xylene	0.1 ppm	5 ppm	50 ppm	<300 ppb
lead	375 ppm	500 ppm	1000 ppm	10 ppb

Jurisdiction/Agency:

Ontario Ministry of the Environment
Waste Management Branch
1989 Decommissioning Guidelines

Approach:

Generic guidelines for the clean up of decommissioned sites and facilities in Ontario.

Description and Rationale:

The guidelines provide clean up criteria (particularly for metals) according to proposed land uses.

Criteria:

	Agricultural/Residential/Parkland		Commercial/Industrial	
Contaminant	Medium/ Fine Soils	Coarse Soils	Medium/Fine Soils	Coarse Soils
lead	500 ppm	375 ppm	1000 ppm	750 ppm
oil and grease (%)	1*	1	1	1

* 2% for weathered (exposed > 2yrs) oil

Jurisdiction/Agency:

Nova Scotia

Approach:

Two tier/three level approach according to land use and proximity to well water. Tier 1 criteria are below; tier 2 allows the proponent to present site specific assessment criteria if tier 1 not practicable.

Description and Rationale:

Level I: Residential or institutional building or a third party water well within 30 metres.

Level II: Commercial site or residential building, institutional building or third party well within 100 metres downgradient or 50 metres upgradient.

Level III: Industrial site or a commercial, residential, or institutional building outside of 100 metres downgradient or 50 metres upgradient.

Criteria:

Nova Scotia Soil Criteria Values (ppm)			
Contaminant	Level I	Level II	Level III
BTEX	1.0	2.0	200
Benzene	0.05	0.5	2.0
TPH	100	400	2000

Jurisdiction/Agency:

Prince Edward Island

Approach:

Two levels of site sensitivity based on the location of water wells.

Description and Rationale:

Level I: Any site in a recharge area within the hydrogeological cycle where more than one water well is within 250 metres.

Level II: Any site in a discharge or recharge area where the distance to a water well is greater than 250 metres.

Criteria:

Soil and Groundwater Remediation Criteria (ppm)				
	Soil		Groundwater	
Contaminant	Level I	Level II	Level I	Level II
BTEX	ND	2.0		
Benzene	ND	0.5		
Toluene			0.024	50
Ethylbenzene			0.0024	2.4
Xylenes			0.300	300
TPH	50	400		

Jurisdiction/Agency:

New Brunswick (proposed September, 1991)

Approach:

Three levels considering land use and groundwater protection. Based on the Quebec andf Alberta guidelines.

Description and Rationale:

Level I: High sensitivity is agricultural or residential land where groundwater is being used or there is acute environmental sensitivity.

Level II: Moderate sensitivity is residential or parkland where groundwater is not being used.

Level III: Low sensitivity is commercial or industrial land.

Criteria:

Proposed Soil and Groundwater Standards						
	Soil Criteria (ppm)			Groundwater Criteria (ppb)		
Contaminant	I	II	III	I	II	III
benzene	0.05	0.5	5	0.5	5	50
toluene	0.1	3	30	0.5	24	200
ethylbenzene	0.1	5	50	0.5	3	50
xylenes	0.1	5	50	0.5	300	2000
TPH	5	20	100	20	200	2000

Jurisdiction/Agency:

Saskatchewan (December, 1991)

Approach:

Two levels of site sensitivity primarily based on current and future land use. Criteria are from the Alberta MUST guidelines.

Description and Rationale:

Level I: residential or agricultural land or areas with acute sensitivity to environmental stresses.

Level II: sites which are presently and will be used for commercial and industrial purposes for the foreseeable future.

Criteria:

Interim Cleanup Criteria for Soil and Groundwater				
	Soil Criteria (ppm)		Groundwater Criteria (ppm)	
Contaminant	Level I	Level II	Level I	Level II
Benzene	0.05	0.5	0.005	0.065
Toluene	1.0	10	0.024	0.300
Ethylbenzene	0.5	5	0.002	0.700
Xylenes	1.0	5	0.300	5
TPH	40	400	0.200	50
Phenols	0.05	1.0	0.002	0.100
Lead	50	200	0.050	0.050

Jurisdiction/Agency:

North Carolina

Approach:

Site sensitivity analysis of petroleum contaminated soils followed by clean up to one of 4 prescribed levels.

Description and Rationale:

A standardized site sensitivity analysis (which considers primarily the potential for contamination of groundwater through an examination of site physical factors and not potential human receptor impact) is conducted by a consultant on behalf of the Proponent. Depending on the evaluation, the site is then cleaned up according to prescribed levels (below) after approval by the regulatory agency. This site sensitivity analysis does not apply to 1) soils with < 10 ppm TPH (no remediation required) 2) soils located >5 feet from the seasonal high water table or top of bedrock or 3) soils which create a human exposure pathway via ingestion, inhalation, or absorption.

Criteria:

Soil Action Levels (General):	
TPH	10 ppm
Halogenated Hydrocarbons	detection limits
lead	0.5 ppm
Site Sensitivity Action Levels:	
Score	Clean Up Levels
>44 (high sensitivity)	10 ppm TPH
36-43	35 ppm TPH
21-35	60 ppm TPH
5-20	85 ppm TPH

Jurisdiction/Agency:

New York

Approach:

Contaminant-specific guidelines

Description and Rationale:

Primarily based on groundwater protection: Soil guidance values (Cs) for volatiles (BTEX) are calculated using the formula Cs = f X Koc X Cw where f is the fraction of total organic matter in soil (assumed 2.5%), Koc is the soil water partition coefficient, and Cw is the lower of the allowable groundwater or drinking water standards (ppb)(EPA Health or N.Y. State Health Department-based).

Criteria:

Contaminant	GW/DW Standard (ppb)	Soil Guidance Value (ppb)
benzene	0.7	1.5
toluene	5	37.5
ethylbenzene	5	137.5
xylenes	5	300
PAHs (specific)		

Jurisdiction/Agency:

Florida (February, 1991)

Approach:

Generic

Description and Rationale:

A generic approach was adopted because of the large number of sites. Field methods of analysis as opposed to laboratory analyses were adopted due to time and cost considerations. Total hydrocarbons present, rather than particular compounds, are analyzed because the volatile and polynuclear aromatics only make up a small percentage of the fuel constituents. The remaining compounds may be equally as harmful. Criteria numbers are based on Florida Administrative Codes for clean soils; rationale not available.

Criteria:

Gasoline: 500 ppm TPH

Kerosene and mixed products: 50 ppm TPH

Lead: 5 ppm (TCLP); 77 ppm (total)

Jurisdiction/Agency:

New Hampshire (September, 1991)

Approach:

Generic guidelines for soils contaminated by petroleum spills or releases except where the state regulatory agency feels site-specific goals are necessary (i.e. wellhead protection areas, sensitive wildlife habitats, densely populated areas).

Description and Rationale:

Remediation goals were calculated using the Leaching Potential Analysis for gasoline and diesel fuels (California LUFT program) adjusted for New Hampshire meteorological and hydrogeological conditions. Using site physical factors, the analyses estimate the concentrations of BTEX and TPH that can be left on-site without threatening groundwater. Both TPH and BTEX are examined because, depending on the volatility of the petroleum product spilled, the nature of the contaminated soil, and the age of the spill/release, analysis for the more volatile BTEX components may not be sufficient

Criteria:

Contaminant	Soil Levels	Groundwater
BTEX	1.0 ppm	1.0 ppm
gasoline TPH	10 ppm	
diesel TPH	100 ppm	100 ppm

Jurisdiction/Agency:

Idaho

Approach:

Criteria which, although may be applied to most sites, should be considered on a site to site basis.

Description and Rationale:

Soil values (TPH) are taken from the California LUFT program guidelines. Groundwater values are mainly drinking water EPA Maximum Contaminant Levels or Goals.

Criteria:

Contaminant	Soil Values	Groundwater Values
benzene		5 ppb
Gasoline TPH	100 ppm	
Diesel TPH	1000 ppm	
Volatile Organic Aromatics		50 ppb

Jurisdiction/Agency:

Illinois (September, 1991)

Approach:

Generic clean-up objectives.

Description and Rationale:

Sites must be assessed by a qualified consulting engineer and remediation plans approved by the state agency responsible. Clean-up objectives other than the generic levels are determined on a case-by-case basis. Rationale for soil and water objectives are not given.

Criteria:

Contaminant	Soil Objective	Groundwater Objective
benzene	0.005 ppm	0.005 ppm
BTEX	11.705 ppm	11.705 ppm
lead	site-specific	site-specific
non-carcinogenic PAHs	4.2 ppm	0.21 ppm
carcinogenic PAHs	0.004 ppm	0.0002 ppm

Jurisdiction/Agency:

Washington (July, 1991)

Approach:

Based on the Washington State Toxics Control Act. Clean-up levels were established which cover most sites contaminated with hazardous substances. Site-specific guidelines are used in sites deemed to be exceptionally contaminated.

Description and rationale:

Method A clean-up levels (below) are used under normal circumstances and govern clean-up of most substances at petroleum contaminated sites. These levels were "developed using acceptable risk levels outlined in the standards and health-based concentrations included in other applicable state and federal laws". Method B levels allow for clean up levels that protect groundwater and consider such factors as contaminant types, depth to groundwater, and rainfall. Method C levels may be used for substances not found in Method A or for sites exceptionally contaminated or which pose an exceptional risk to groundwater and human health. These levels are determined by site-specific risk assessments. Remediation must comply with local air quality standards.

Criteria:

Contaminant	Groundwater Action Level	Soil Action Level
benzene	5 ppb	0.5 ppm
ethylbenzene	30 ppb	20 ppb
toluene	40 ppb	40 ppm
xylenes	20 ppb	20 ppm
Gasoline TPH	1000 ppb	100 ppm
Diesel & other TPH	1000 ppb	200 ppm
Total lead	5 ppb	250 ppm

Jurisdiction/Agency:

Kansas (September, 1991)

Approach:

Generic guidelines for soil and groundwater clean-up associated with UST removals.

Description and Rationale:

No rationale for soil levels given; groundwater levels are EPA Health based.

Criteria:

Contaminant	Soil Remediation Level	Groundwater Remediation Level
benzene	1.4 ppm	5 ppb[1]
ethylbenzene		680 ppb[2]
toluene		2000 ppb[2]
xylene		440 ppb[2]
BTEX	100 ppm	
TPH	100 ppm	
lead		50 ppb

[1] EPA Maximum Contaminant Level

[2] EPA Maximum Contaminant Level Goals

Jurisdiction/Agency:

California (October, 1989)

Approach:

Site specific analysis

Description and Rationale:

a) Site investigation to determine category i.e. category 1 is no evidence of significant soil or groundwater contamination, category 2 is evidence of soil contamination, and category 3 is evidence of soil and groundwater contamination.

b) For category 1 sites a leaching potential analysis is conducted for TPH and BTEX which estimates the levels which may remain and not pose a threat to groundwater.

c) For category 2 sites a further general risk appraisal and computer modelling is conducted to estimate the risk to groundwater and clean-up levels of TPH and BTEX.

d) For category 3 sites clean-up levels are determined by c) but remediation is carried out on a site specific basis.

Criteria:

Contaminant	Maximum Allowable Levels
benzene	0.3-1.0 ppm
ethylbenzene	1-50 ppm
toluene	0.3-50 ppm
xylene	1-50 ppm
gasoline TPH	10-1000 ppm
diesel TPH	100-10,000 ppm

Jurisdiction/Agency:

Michigan (August, 1991)

Approach:

Generic remediation of sites.

Description and Rationale:

Michigan DNR approved clean-up may be either to background/method of detection limits (Type A Criteria) or to Type B criteria. The Type B criteria for groundwater are primarily based on EPA health-based Maximum Contaminant Levels for drinking water. Aesthetic values for groundwater are currently being developed.

Criteria:

Contaminant	Soil	Groundwater Health-Based	Groundwater Aesthetic
benzene	20 ppb	1 ppb	
ethylbenzene	600 ppb	700 ppb	70
toluene	800 ppb	1,000 ppb	800 ppb
xylene	400 ppb	10,000 ppb	300 ppb

Jurisdiction/Agency:

New Mexico (July, 1990)

Approach:

Generic

Description and Rationale:

No rationale given for soil values. The UST program provides for initial reporting and abatement procedures, and requires extensive site and hydrogeological investigations.

Criteria:

Contaminant	Maximum Soil Level
benzene	10 ppm
total aromatic hydrocarbons	50 ppm (lab test) 100 ppm (field test)
TPH	100 ppm (diesel)

APPENDIX B:
Typical Hydraulic Conductivities of Subsurface Materials

Typical Hydraulic Conductivities of Subsurface Materials*	
Gravel	$> 10^{-1}$ cm/s
Clean Sand	5×10^{-4} to 1 cm/s
Silty Sand	10^{-5} to 10^{-1} cm/s
Silt	10^{-7} to 10^{-3} cm/s
Glacial Till	10^{-10} to 10^{-4} cm/s
Unweathered Marine Clay	10^{-10} to 10^{-7} cm/s
Fractured Igneous and Metamorphic Igneous Rocks	10^{-6} to 10^{-2} cm/s
Limestone and Dolostone	10^{-7} to 10^{-4} cm/s
Sandstone	10^{-8} to 10^{-4} cm/s
Shale	$<10^{-11}$ to 10^{-7} cm/s
Unfractured Igneous and Metamorphic Igneous Rocks	$<10^{-11}$ to 10^{-8} cm/s

* Reference: Freeze, R.A. and J.A.Cherry, 1979. "Groundwater". Prentice-Hall, 604 pp. (p.29).